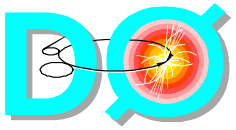
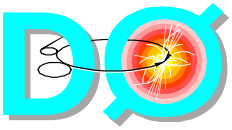
DØ High Voltage System Tutorial

J. Frederick Bartlett



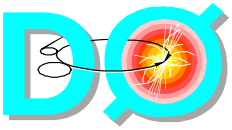
Outline

- Introduction to the HV Hardware
- Control System Features
- Operator GUI Programs
- Diagnostic Guidelines



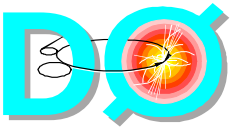
Hardware

- **High Voltage VME crate**
  - **6U size**
  - **Custom backplane**
  - **Additional voltage supplies**
    - **+5V Digital, +- 12V Analog, +-12 V Bulk**
- **Fermilab/BiRa 4877 module**
  - **Six modules per VME crate**
  - **8 channels per module**
  - **10 voltage generator pod types**
  - **Cockroft-Walton generator**
  - **Backplane trip links**
  - **Backplane module address encoding (geographical)**

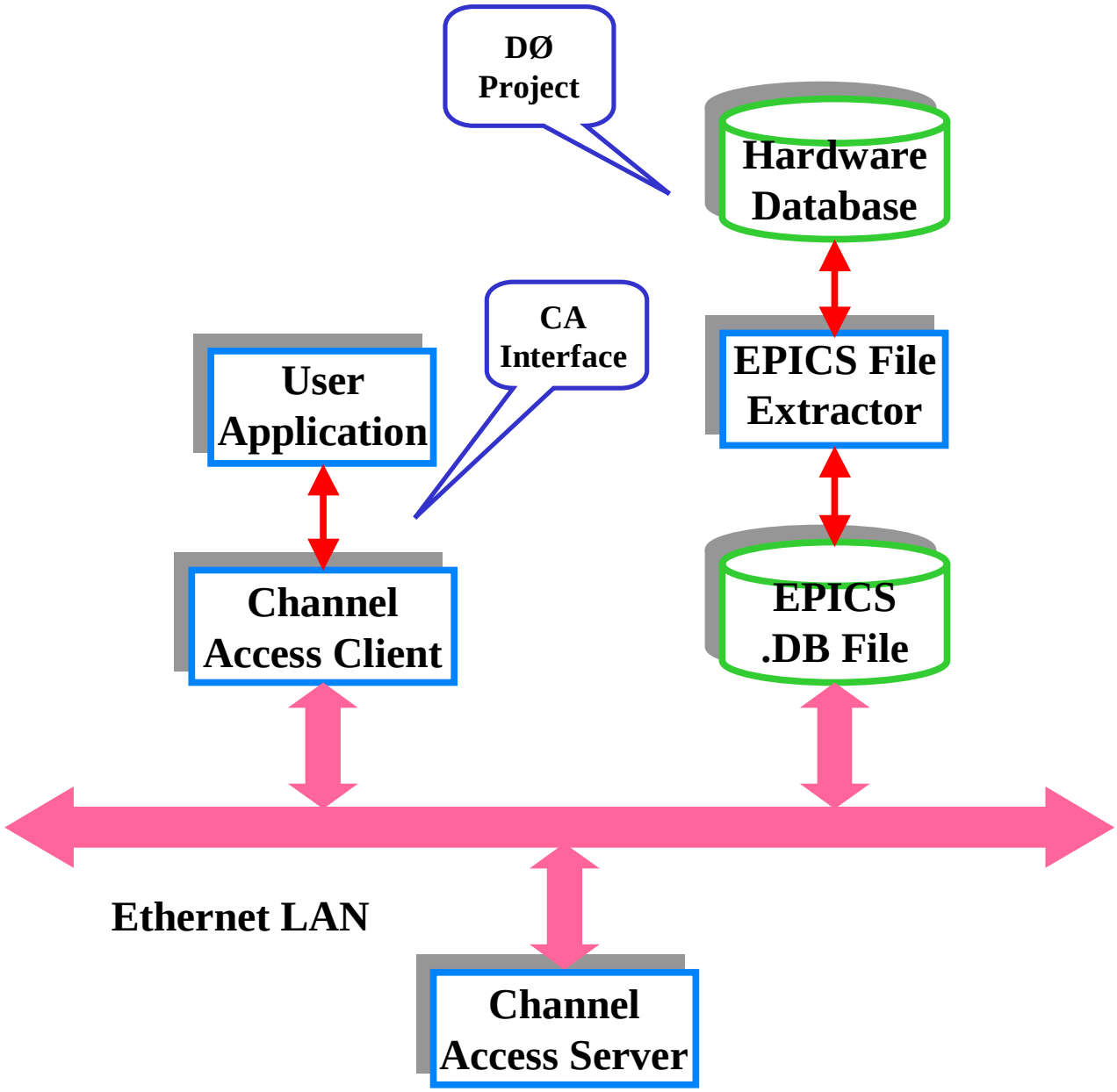


Hardware

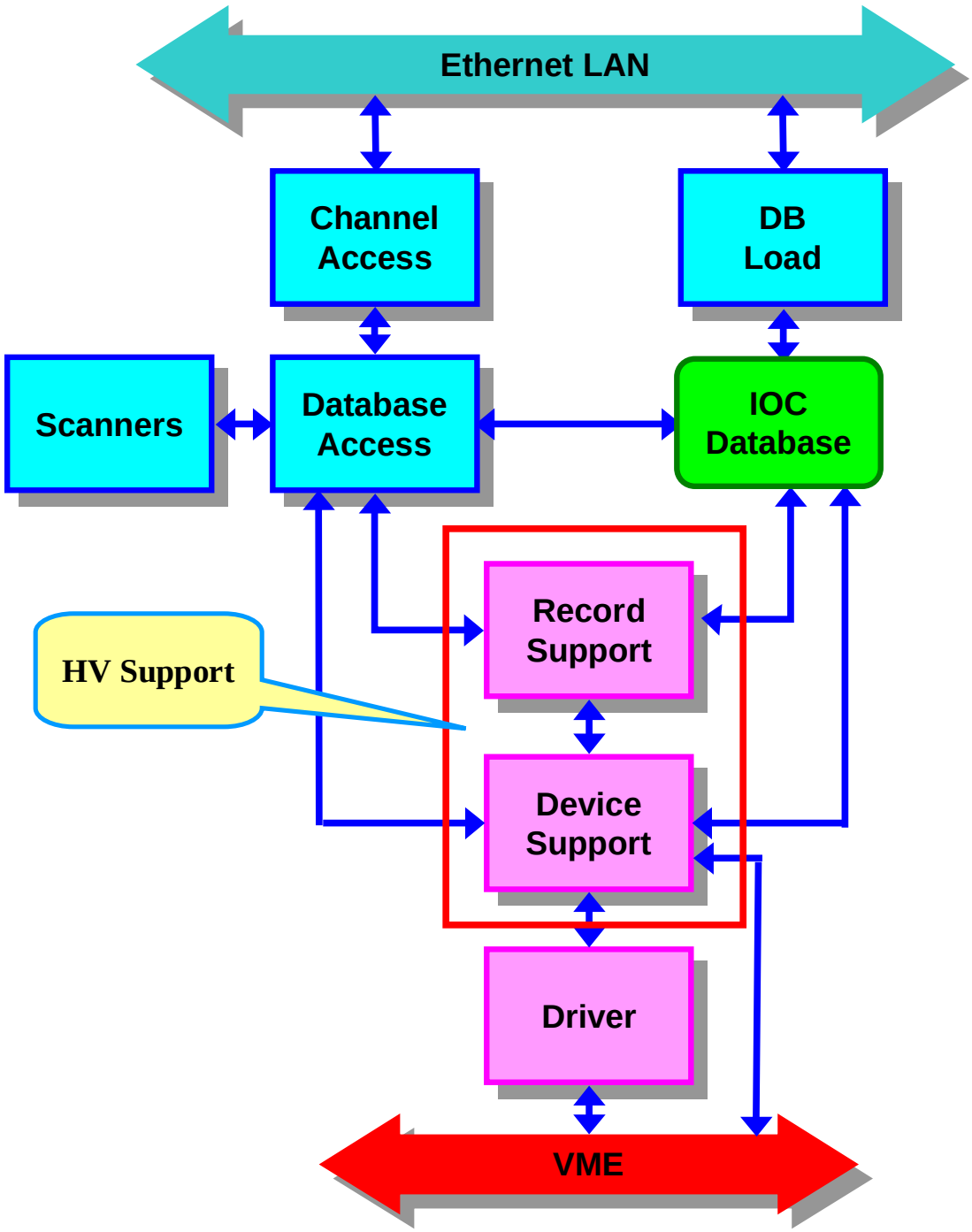
- Reference
  - Bi Ra - “Model VME 4877PS High Voltage Power Supply System Manual”



EPICS Components

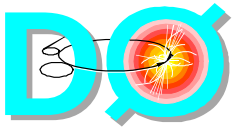


EPICS IOC Components



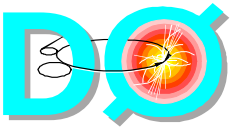
EPICS High Voltage Support

- Record support
  - hv - single HV channel
  - hvtrip - common trip group of HV channels
- Device support
  - Fermilab/Bi Ra 4877



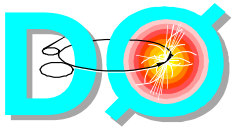
EPICS Record Support

- **HV Record - hv**
  - **High-level device interface**
  - **Sequential state machine model (limited implementation of UML Harel diagrams)**
  - **Optional fast and slow histories (not implemented)**
  - **Corrective ramp algorithm**
- **Trip record - hvtrip (not implemented)**
  - **Forms trip groups at the record level**



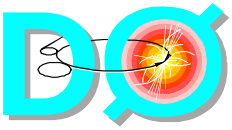
HV Record

- Purpose
  - Control and monitor an individual HV channel
  - Add high-level operations to a basic voltage generator
- Implemented as a sequential state machine with states, transitions, actions, and events
- Ramping to a target voltage is a software function



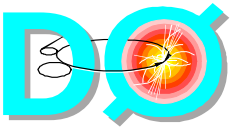
HV Record - Database Fields

- **Readback**
  - **Voltage**
  - **Current**
  - **State**
  - **Voltage trip level**
- **Setting**
  - **Command**
  - **Target voltage**
  - **Current trip level**
  - **Current ramp factor**
  - **Ramp rate**
  - **Setting tolerance**

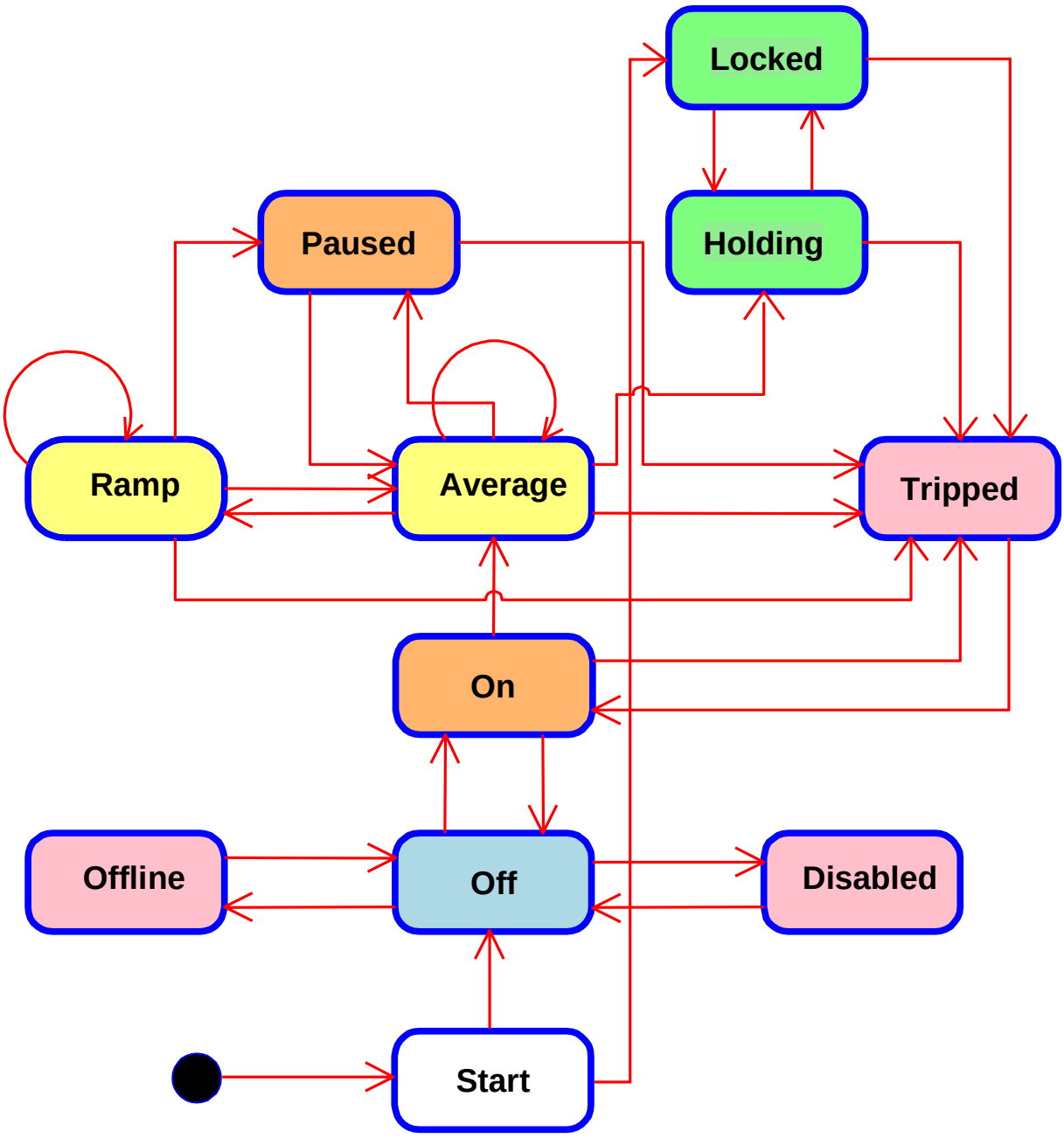


HV Record - Pod Types

Pod Name	Max Voltage	Max Current
P5.5KV1	+5.5kV	2.3 mA
M5.5KV1	-5.5 kV	2.3 mA
P5.5KV2	+5.5 kV	1.0 mA
M5.5KV2	-5.5 kV	1.0 mA
P5.5KV3	+5.5 kV	0.1 MA
M5.5KV3	-5.5 kV	0.1 mA
P3.5KV	+3.5 kV	3.5 mA
M3.5KV	-3.5kV	3.5 mA
P2.0KV	+2.0 kV	3.2 mA
M10V1	-10 V	0.2 mA

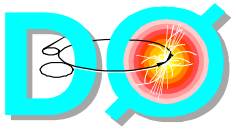


HV Record - State Diagram



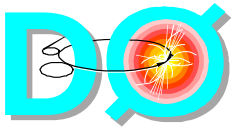
HV Record - Ramp Algorithm

- Set current trip to ramp value
  - Determined by current ramp factor field
- Compute average voltage
- Compute voltage step size and number of steps to reach target voltage
- Execute ramp steps
- Compute average voltage



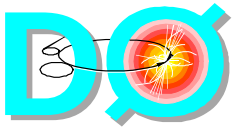
HV Record - Ramp Algorithm

- Compare abs($V_{average}$ - V_{target}) with $V_{tolerance}$
  - less or equal - Enter HOLDING state
  - greater - Repeat ramp sequence
- If the number of ramp cycles exceeds the limit, enter the PAUSE state and set an alarm condition



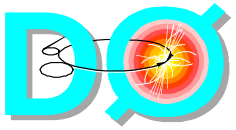
Initialization Modes

- **Standard**
  - Output voltage set to zero
  - Initial state is OFF
- **Alternative**
  - Output voltage unaltered
  - Initial state is LOCKED
  - Required by calorimeter



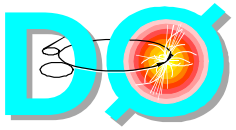
HV Record - Trips

- Channel
  - Overvoltage
    - Trimpot setting
  - Overcurrent
    - Register setting
  - External
    - Backplane connection
- Module
  - Watchdog
    - Module access timeout
  - Interlock
    - Front panel connector
  - External
    - Backplane connection



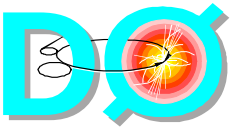
HV Record - Planned Extensions

- Slow history buffer
  - Sample rate: ~ 0.05 Hz
  - Voltage, current, and state recorded in circular buffers
  - Low pass filter
- Fast history buffer
  - Sample rate: ~ 30-60 Hz
  - Voltage, current, and state recorded in circular buffers
  - Buffer update algorithm
    - After a trip the buffer continues to collect readings for a specified time period after which it is locked



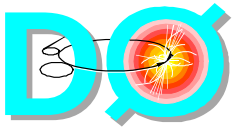
Operator GUI Programs

- **Utility display**
  - **Monitor crate parameters (backplane voltages and temperature)**
- **Detector display**
  - **Monitor channel state for multiple crates**
  - **Control state change for multiple crates**
- **Crate display**
  - **Monitor channel parameters for a single crate**
  - **Control state change for single channel or all channels**

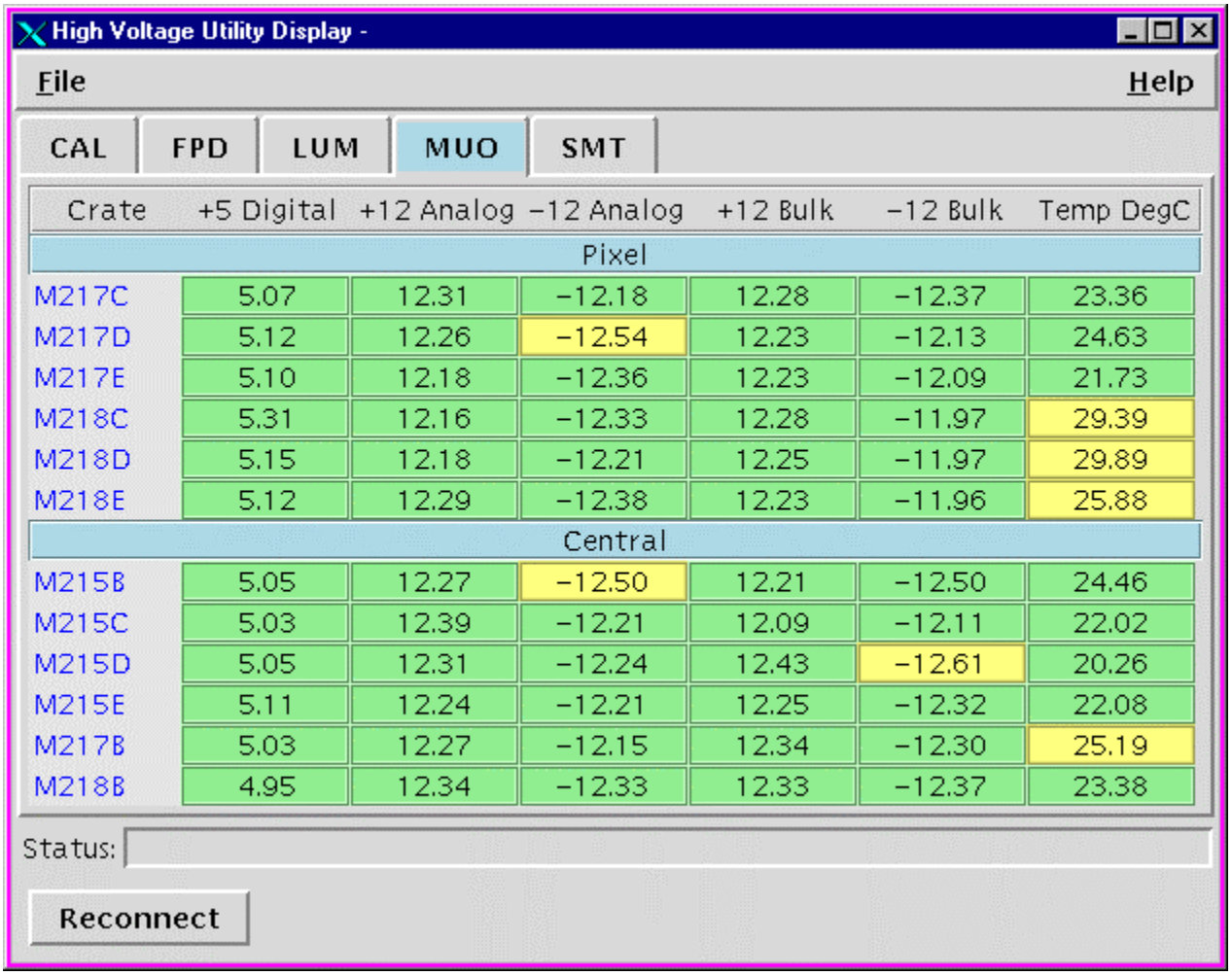


Operator GUI Programs

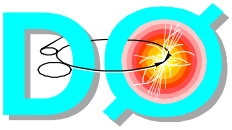
- **Product setup required for all displays**
  - **setup onl_apps**



Utility Display

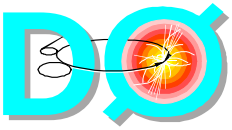


Crate	+5 Digital	+12 Analog	−12 Analog	+12 Bulk	−12 Bulk	Temp DegC
Pixel						
M217C	5.07	12.31	−12.18	12.28	−12.37	23.36
M217D	5.12	12.26	−12.54	12.23	−12.13	24.63
M217E	5.10	12.18	−12.36	12.23	−12.09	21.73
M218C	5.31	12.16	−12.33	12.28	−11.97	29.39
M218D	5.15	12.18	−12.21	12.25	−11.97	29.89
M218E	5.12	12.29	−12.38	12.23	−11.96	25.88
Central						
M215B	5.05	12.27	−12.50	12.21	−12.50	24.46
M215C	5.03	12.39	−12.21	12.09	−12.11	22.02
M215D	5.05	12.31	−12.24	12.43	−12.61	20.26
M215E	5.11	12.24	−12.21	12.25	−12.32	22.08
M217B	5.03	12.27	−12.15	12.34	−12.30	25.19
M218B	4.95	12.34	−12.33	12.33	−12.37	23.38

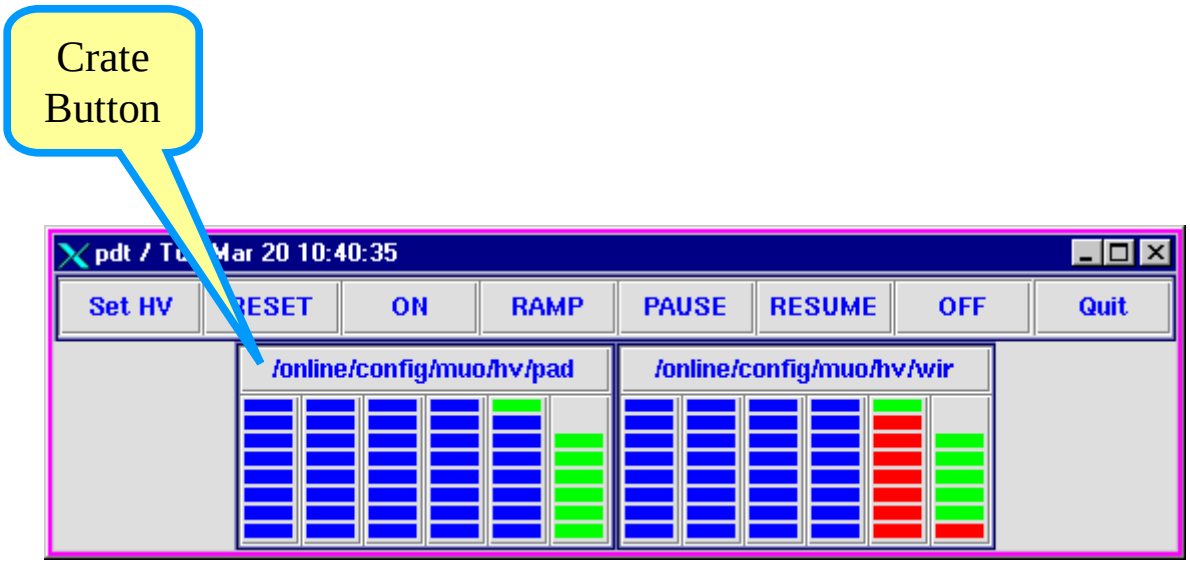


Utility Display

- Purpose
  - Monitor HV crate parameters
    - Backplane voltages
    - Temperature
- Properties
  - Organized by page
  - Read-only access
- Implementation
  - Python script
  - Program name - HvuGui.py
  - Configuration scripts - xxx.hvu
- Self executing file
  - /online/config/ctl/mch.hvu

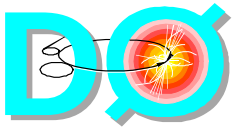


Detector Display



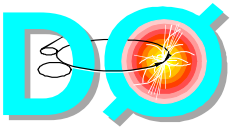
Detector Display

- Purpose
  - Monitor state of channels in multiple crates
  - Execute multiple-crate actions
  - Initiate crate display
- Properties
  - Organized by crate
  - Multi-crate action buttons
- Implementation
  - Python script
  - Program name - hv_det.py
  - Configuration script - xxx.hvd



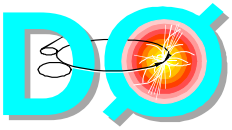
Detector Display

- **Crate button**
  - **Start crate display**
- **Action buttons**
  - **SET HV - set to a target voltage**
  - **RESET - reset tripped channels**
  - **ON - set channels to ON state**
  - **RAMP - ramp channels to target voltage**
  - **PAUSE - pause ramp**
  - **RESUME - resume ramp**
  - **OFF - set channels to OFF state**



Detector Display

- Channel state colors
  - Black/Red - OFFLINE, DISABLED, TRIPPED
  - Blue - OFF
  - Green - HOLDING, LOCKED
  - Orange - ON
  - Yellow - AVERAGE, RAMP, PAUSED



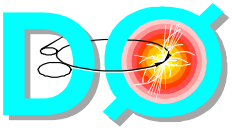
Crate Display

pcn / Tue Mar 20 15:12:05

Set HV | RESET | ON | RAMP | PAUSE | RESUME | OFF | Quit

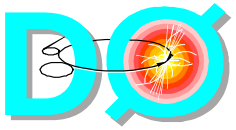
0
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

	V_trip	I_trip	V_max	V_set	V_read	I_read	Control
	-1700	2500	-1620	-1620	-0.3	-0.3	Off
	-1701	2500	-1640	-1640	-1.1	0.8	Off
	-1769	2500	-1660	-1660	-0.1	0.0	Off
	-1789	2500	-1710	-1710	0.6	0.6	Disabled
	-1789	2500	-1710	-1710	-1.0	1.3	Off
	-1788	2500	-1680	-1680	0.4	-0.4	Off
	-1695	2500	-1620	-1620	-0.0	0.7	Off
	-1691	2500	-1640	-1640	-0.0	0.1	Off
PCN09	-1792	2500	-1660	-1660	0.3	0.2	Off
PCN10	-1700	2500	-1640	-1640	0.5	0.5	Off
PCN11	-1799	2500	-1700	-1700	0.1	1.5	Off
PCN12	-1794	2500	-1670	-1670	0.1	0.8	Off
PCN13	-1698	2500	-1560	-1560	0.2	0.3	Off
PCN14	-1699	2500	-1580	-1580	-1.5	1.5	Off
PCN15	-1696	2500	-1630	-1630	0.9	0.2	Off
PCN16	-1695	2500	-1630	-1630	-0.2	0.6	Off
PCN17	-1793	2500	-1730	-1730	-0.4	1.7	Off
PCN18	-1697	2500	-1640	-1640	-1640	1076	Holding
PCN19	-1697	2500	-1570	-1570	-1569	1829	Holding
PCN20	-1695	2500	-1570	-1570	-1568	1830	Holding
PCN21	-1700	2500	-1570	-1570	-1571	1836	Holding
PCN22	-1698	2500	-1600	-1600	-1599	1871	Holding
PCN23	-1788	2500	-1720	-1720	-1719	1505	Holding
PCN24	-1685	2500	-1590	-1590	-1589	1387	Holding



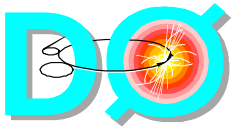
Crate Display

- **Purpose**
  - Monitor individual channels
    - State
    - Voltage and current readback
    - Target voltage
    - Voltage and current trip levels
  - Execute all-channel and individual channel actions
  - Set all-channel and individual channel target voltages
  - Usually organized by crate



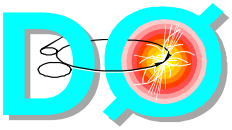
Crate Display

- Properties
  - Organized by channel
  - Multi-channel action buttons
  - Channel action menu button
- Implementation
  - Python script
  - Program name - hv_crate.py
  - Configuration script - xxx.hvc
- Action buttons
  - Same as Detector display
- Channel state colors
  - Same as Detector display



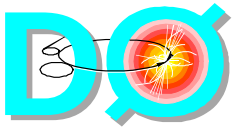
Crate Display

- Planned extensions
  - Paged GUI display format
  - Optional display of additional channel parameters
    - Ramp rate, scaling factor, …
  - Time plot generation



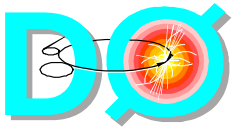
Diagnostic Guidelines

- Channel is in DISABLED state
  - Missing module
  - Incorrect pod type in database
  - Module does not respond
- Module trips after transition from OFF to ON state
  - After a period with the power off, the channel may not be stable. Leave the power on for several hours, after which the channel may recover.
  - Bad module



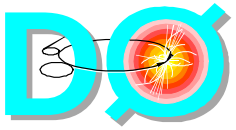
Diagnostic Guidelines

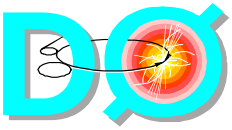
- Module trips during ramp but has not exceeded either the voltage or current trip limit
  - After a period with the power off or the channel in the OFF state, the channel may not be stable. Leave the channel in the ON state at zero output for several hours, after which the channel may recover
  - Bad module



Diagnostic Guidelines

- Ramp does not converge to target voltage
  - Record tuning parameters set incorrectly
    - Call an expert for this
  - Bad module
- Current trip during ramp caused by capacitance charging
  - Reduce ramp rate
  - Increase current scaling factor parameter



Diagnostic Guidelines

- **Output voltage is unstable (noise)**
  - **One of the bulk +-12V supply voltages is missing. Use the HV utility program to check**